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**Seeing How it Sounds: Observation, Imitation and Improved Learning in Piano
Playing**

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Abstract

Research in various fields has shown that students benefit from teacher action demonstrations during instruction, establishing the need to better understand the effectiveness of different demonstration types across student proficiency levels. This study centres upon a piano learning and teaching environment in which beginners and intermediate piano students (N=48) learning to perform a specific type of staccato were submitted to three different (group exclusive) teaching conditions: *audio-only* demonstration of the musical task; observation of the teacher's action demonstration followed by student imitation (*blocked-observation*); and observation of the teacher's action demonstration whilst alternating imitation of the task with the teacher's performance (*interleaved-observation*). Learning was measured in relation to students' range of wrist amplitude (RWA) and ratio of sound and inter-sound duration (SIDR) before, during and after training. Observation and imitation of the teacher's action demonstrations had a beneficial effect on students' staccato knowledge retention at different times after training: Students submitted to interleaved-observation presented significantly shorter note duration and larger wrist rotation, and as such, were more proficient at the learned technique in each of the lesson and retention tests than students in the other learning conditions. There were no significant differences in performance or retention for students of different proficiency levels. These findings have relevant implications for instrumental music pedagogy and other contexts where embodied action is an essential aspect of the learning process.

Keywords: music teaching, music learning, demonstration, skill, observation; imitation

Introduction

Teachers' demonstrations are instances where teachers perform a certain intended skill or technique for the student to observe/listen and learn from. In piano and other instrumental music pedagogical contexts demonstrations are an integral aspect of teaching and learning (Kohut, 1985; Radocy & Boyle, 1997), acknowledged among teachers' preferred teaching strategies (Zhukov, 2004). Frequently used demonstrations in instrumental music settings include: singing, humming, clapping rhythmical patterns and performing musical phrases while emphasising or marking a critical feature/s of the task – such as the type of action or gesture required to achieve intended sound qualities. Where music needs to be embodied and physically performed teachers' demonstrations provide students with an understanding of the movement-to-be-performed in terms of trajectory, direction, amplitude, intensity and the sound or tone quality intended from such movement.

Empirical evidence suggests a highly beneficial role for learning as a result of demonstrations in contexts such as social learning, sports, physical education (Bandura, 1986; Magill, 2007; Mattar & Gribble, 2005; Scully, D., & Newell, 1985; Shea, Wright, Wulf, & Whitacre, 2000) and education, particularly in relation to maths learning and more focused on gesture (see Cook, Press, Dickinson, & Heyes, 2010; Cook, Duffy, & Fenn, 2013; Goldin-Meadow et al., 2012). However, despite some work undertaken in instrumental music pedagogical settings, there remains a lack of evidence regarding the effectiveness of teachers' demonstrations for student learning. Firstly, research projects dedicated to studying instrumental music teacher demonstrations have based their findings on judges rating student performances rather than on accurate testing of student knowledge retention and transfer (e.g. Baxter & Stauffer, 1988; Goolsby, 1997; Rosenthal, 1984; Sang, 1987; Siebenaler, 1997). As such, most of the positive beliefs held in relation to demonstration stem from personal views and experiences in association with certain teaching strategies. Nevertheless, in this context

it is argued that demonstrations facilitate faster learning (in opposition to verbal only directives), particularly in aspects such as adequate body posture and grasping characteristics of a certain motion (Zhukov, 2004), and this resonates with findings of sports and physical rehabilitation research (see Magill, 2007). Despite being an integral aspect of learning and teaching instrumental music (Kohut, 1985; Radocy & Boyle, 1997) the imitational aspect intrinsically related to learning through demonstration has been met with some levels of opposition by a few professionals. The argument raised by these individuals considers a possible conflict between imitational teaching and student development of interpretative meaning-construction (Rodrigues, H., Rodrigues, P. & Correia, 2009) where imitation is viewed as potentially harnessing the development of students' creativity and personal musical interpretation. This casts further doubt about what teaching methods should be selected in pursuing students' learning effectiveness.

Additionally, the emphasis placed by teachers upon musical notation at the earliest stages of learning (mainly the focus on pitch and rhythmical elements) at the expense of a higher focus on motor, gestural and expressive considerations has been argued as leading to decreased aural and bodily sensitivity to the natural unified patterns that children spontaneously observe when playing music (McPherson & Gabrielsson, 2002; Mills & McPherson, 2006). This so happens due to the fact that the training of music educators tends to be firmly focused on content and curriculum rather than on the development of musical interactive teaching and learning styles that can promote efficient learning (Young, 2005). . Consequently, there remains a general misunderstanding of the dual conceptual *and physical* nature of teaching and learning to play musical instruments contradictory to current educational trends in music education and performance which suggest a decisive relationship between action and gestural demonstrations, body movements and music learning (e.g. Dogantan-Dack, 2011; Haga, 2008; Haviland, 2011; Juntunen & Hyvönen, 2004; Leman &

Godoy, 2010; Dahl & Friberg, 2007; Davidson, 1994, 2001, 2005; Nafisi, 2013; Rahaim, 2008, 2012; Simones, Rodger, & Schroeder, 2015a; Simones, Schroeder, & Rodger, 2015b)

Considering the musical learner in teaching strategies

Learning to play a musical instrument requires knowledge of the relationship between the motor actions required to deal with the musical instrument and the auditory consequences of such actions (Maes, Leman, Palmer, & Wanderley, 2014). Such knowledge is acquired gradually, through the arbitrary actions involved in instrument manipulation versus the (at least initially) unexpected auditory events (Hommel, 2003). In this explorative process of interaction, systematic repetitions lead to a process of association between the sounds and sound-producing-actions (Maes et al., 2014). For such reason learning to play a musical instrument can be considered as an illustrative case of sensory-motor association learning in which action and perception become intrinsically interwoven (Maes et al., 2014). As argued by the Associative Sequence Learning hypothesis (Heyes, 2010; Cook et al., 2010; Cooper, Cook, Dickinson, & Heyes, 2013; Heyes & Ray, 2000) associations between sensory and motor representations are acquired during development as a result of correlated sensorimotor experience. Examples of correlated sensorimotor experience include synchronous action such as dance and sports where people execute and observe similar actions and in the process, acquire equivalent experience. As a consequence of paired 'doing' and 'seeing' links are established which allow action observation to prime action execution through a process of mediation by mechanisms of associative learning.

Evidence from neuroscience provides support for this hypothesis suggesting that people who were submitted to intensive and long-term processes of skill acquisition develop auditory-motor links as a result of training (Bangert & Altenmüller, 2003; D'Ausilio, Altenmüller, Olivetti Belardinelli, & Lotze, 2006; Herholz & Zatorre, 2012; Brown & Palmer, 2013). Such research focused essentially on expert music performers and heavily

relied on the use of brain imagery techniques remaining unclear what demonstration strategies teachers should use to promote association between intended sounds and motor actions in meaningful ways. In instrumental music evidence suggests that teachers demonstrate more when teaching beginners with demonstrations occurring more frequently in the first stages of student engagement with the music repertoire (Zhukov, 2004); and expert teachers use demonstration more frequently than novice or student teachers (Goolsby, 1997). The rationale behind the use of such approaches and student learning effectiveness as a result are so far unknown. A possible reason for this could be that teachers perceive that beginner students need or can benefit more from demonstrations than more advanced learners. Yet there is no evidence that more advanced students, including those at intermediate levels, would not equally benefit from frequent demonstrations. The 'more or less' frequent correlation between age and proficiency levels (not as fixed in instrumental music learning as in other school subjects) where beginner students are usually children and intermediate students are teenagers or adults could perhaps help explaining the above facts as children have a greater tendency to achieve movement outcome goals (e.g. task accuracy) than adults. (Ashford, Davids, & Bennett, 2007; Wohlschläger, Gattis, & Bekkering, 2003). It could be the case that teachers acquire some sort of implicit or explicit knowledge of the above findings through own teaching experiences resulting in demonstrating more to beginners than to other student proficiency levels. Whatever the case, it appears relevant to ask: do beginner students benefit more from teachers' action demonstrations than intermediate students? Or, given intermediate students' comparably higher levels of learning experience, would they achieve appropriate knowledge retention levels regardless of the type of teacher demonstration used (thus implying that they perhaps need less demonstration than beginner students)? And based on the answers to these questions, what type(s) of demonstrations may be best suited to students across different skill levels?

Demonstrations in piano teaching and learning

Rosenthal (1984) compared the effectiveness of four instructional strategies in college music instruction by submitting participants to the following audio recorded conditions: a *verbal instruction only*; a *model instruction only* (using an aural model only); a *combination of verbal and model instructions* and *practice only*. The results suggested that the model-instruction-only-strategy produced greater student learning outcomes evidenced by the number of student-correct-performed-measures, which led the researcher to conclude that aural only conditions (which she considered the equivalent to demonstrations) are effective teaching strategies. However, there is still wide disagreement among teachers about the types of demonstrations which may result in greater student learning: will listening to sound/audio only provide students with greater learning effectiveness? Or will more observation provide better learning outcomes? Or instead, a combination between observation and imitation, and if so what type of combination?

With regard to sound versus motor action, research has shown that sounds *produced* with one's own motor system are more efficiently recognised than sounds that have simply been *perceived* (in which physical sound production did not occur) (MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010). This also applies to spoken words, which are usually more easily remembered when verbally articulated with sound production when compared to words that are either mouthed without sound (Gathercole & Conway, 1988), or listened to without movement (MacDonald & MacLeod, 1998). Similarly, musical melodies performed by pianists on a keyboard with normal auditory feedback were shown to be recognised better than melodies which were only perceived, or that were produced without sound. This was shown in Brown and Palmer's study (2012) in which expert pianists were submitted to four learning conditions: auditory only; motor only; normal performance; and performing along

with sound-only-recordings without hearing the auditory feedback of their own playing. The results suggested that pianists exposed to motor learning (associated with a 'normal' music performance condition) had higher levels of melody auditory recognition in the required melody recognition test – well beyond auditory learning alone. The authors then concluded that sensory-motor associations formed during the learning process provide memory retrieval cues in accordance with previous findings (Hazeltine, Aparicio, Weinstein, & Ivry, 2007) which state that the performance of configural actions (such as playing chords on the guitar or piano) occur in sequence of a learning process and not through a generalised capacity for audio-visuo-motor matching. Although the exact mechanisms of production-based memory recognition are still unknown, there seems to be a strong link between improved recognition and sensorimotor processing of auditory stimuli.

Motor learning research acknowledges that observation, though not as effective as when combined with performing the required actions of a task through one's own motor system, is important for learning (Shebilske, Regian, Arthur, & Jordan, 1992; Shea et al., 2000; Ste-Marie et al., 2012). Arthur et al. (1996) placed two participants learning together and alternating between observing and physically performing a task involving each participant performing half of a task alternately with a partner, who performed the other half. In this study the task involved learning the pilot-gunner and mine-missile components of the Space Fortress task (an experimental game designed to simulate a dynamic and complex aviation environment) (Gopher, 1993). Retention tests have shown that participants who practiced in pairs performed better than participants who were only requested to practice the task physically (individually), leading the authors to conclude that observation opportunities provided through paired learning foster greater learning effectiveness.

Several studies in educational psychology in various fields (e.g. sports, math and language learning) have shown that students learn more efficiently when they are given

repeated exposures to different concepts/skills in shuffled or interleaved ways, rather than blocked. Blocking involves repeated exposure to one concept at a time before the next and interleaving alternating between related skills (e.g. a pianist alternating practice between scales, chords, and arpeggios). A study using Blocked and Interleaved conditions in maths (algebra and geometry) involved teaching seventh graders in middle schools in Florida (United States of America) slope and graph problems for a period of three consecutive months (Rohrer, Dedrick, & Stershic, 2015). The method included keeping teaching unchanged from standard practice and weekly homework worksheets featuring interleaved or blocked design. A final test occurred at two different points in time: one day and one month later. Strikingly, when the test was one day later, scores were 25 percent better for problems trained with interleaving; at one month later, the interleaving advantage grew to 76 percent showing that the interleaving effect is long-term and increases with the passage of time (for reviews on blocked versus interleaved manipulations in maths learning see Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Rohrer, 2012). However, foreign language studies have shown that when interleaved methods were used to learn an entirely unfamiliar language the results were better with blocking, suggesting that either a degree of familiarity with subject materials is needed before interleaving begins or the contents should be quickly and easily understood (e.g. Carpenter & Mueller, 2013).

In motor learning research (predominantly in sports and rehabilitation) several studies indicate that interleaving can improve motor learning. In badminton serves interleaving produced better recall of each serve type and increased ability to handle new situations when compared with blocking (Goode & Magill, 1986) with similar results later reported for basketball (Landin, Hebert, & Fairweather, 1993). Several studies have shown that during training better results have been achieved during blocked practice and when learning was assessed in retention and transfer tests, groups submitted to interleaved conditions showed

better performance results than participants in blocked conditions (e.g. Young, Cohen, & Husak, 1993; Del Rey, 1982; Del Rey, Wughalter, & Carnes, 1987; Goode, 1986; Sekiya, Magill, & Anderson, 1996; Wulf, 1992). For reviews see Brady, 1998; Schmidt & Bjork, 1992; Wulf & Shea, 2002). Nevertheless, skill level and task difficulty have been shown to influence the benefits of interleaving in motor learning, with more pre-training being required for younger, less skilled students and complex tasks (e.g. Farrow & Maschette, 1997; Pinto-Zipp & Gentile, 1995).

If learning to play a musical instrument occurs through sensory-motor association processes (see Heyes, 2010) it makes sense to attempt to grasp understandings about how teachers' demonstration strategies can be optimised to improve learning, not only in regards to expert pianists, but focusing on learners at various learning levels. For the current study, beginner piano students (pre-grade 1 to grade 3) and intermediate proficiency level piano students (grades 4 to 8), were required to learn a specific type of staccato while being submitted to three different (group exclusive) teaching conditions involving blocking and interleaving conditions (more on Method Section). Staccato refers to a particular type of sound articulation in which successive tones are separated by a silence gap and also short in duration (Repp, 1998). Staccato was chosen because, contrary to many other musical tasks, it is possible at this point in time for its sound and gap-between-sounds to be quantified in terms of duration, and to implement describable and quantifiable action demonstration which can enable an objective evaluation of students' knowledge retention.

Bearing the above literature review in mind, in light of the Associative Sequence Learning hypothesis, we would expect students to achieve better retention learning results when they are submitted to demonstrations involving repeated observations. And we would also expect intermediate level students to achieve better learning retention results than beginners, regardless of the type of teaching demonstrations they are submitted to. This is

because students in intermediate proficiency levels (grades 4-8) are in what can be considered as a ‘middle’ learning stage – where, in comparison to beginners, their previous learning experiences should grant them better and more stable links between sounds and the motor actions needed to originate them (Maes et al., 2014; Brown & Palmer, 2013).

Method

Participants

Informed written consent for research participation was obtained for 52 piano students in Belfast, Northern Ireland. After an initial pre-test, 4 participants were excluded (reasons for exclusion are explained in Pre-test Sub-section). The 48 participants accepted for the experiment were divided into two groups according to their piano proficiency levels (in accordance with the requirements of the Associated Board of the Royal Schools of Music (ABRSM)) as follows:

- Beginners: students with piano proficiency levels between pre-grade 1 and grade 3 (a total of 17 females and 8 males, ages ranging from 5 to 14 years).
- Intermediate: students with piano proficiency between grades 4 to 8 (a total 15 females and 8 males, ages ranging from 13 to 44 years).

ABRSM piano examinations entail performance of three contrasting pieces, technical requirements (scales, arpeggios and broken chords), sight reading and aural tests with a balance between legato and staccato being required in all the exam components (for more information see ABRSM Piano Syllabus, Requirements and Information at www.abrsm.org).

Participants’ group division was made to enable considerations on possible results’ differences between students at earlier and intermediate learning stages. Table 1 describes the allocation of participants per teaching condition: their age ranges and average time they have been engaged in formal piano teaching and learning at the time of the experiment.

[Table 1 – Here]

Materials

Both the experiment and associated tests were carried out using the same room and a Yamaha C3 grand piano. Video data were recorded using a Sony high-definition camera (positioned laterally to the piano, facing the keyboard and piano chair, at a height of 1.04 metres and distance of 1.72 metres, capturing images of the researcher and student). Audio recordings of trials were taken using a portable stereo audio recorder (Tascam HD-P2, connected to a microphone at a height of 130 cm and a distance of 57 cm to the piano resonance box). The digital videos were converted to Windows Media files, analysed using Kinovea software (downloaded from <http://www.kinovea.org/>), and the audio data was analysed using Matlab software (Release 2013a, The MathWorks, Inc., Natick, Massachusetts, United States). The audio recording of the staccato task for the audio-only teaching condition was prepared using the above physical, acoustical and recording settings, and was played through the built-in speakers of a Dell Inspiron computer.

Design

The experiment followed a between-groups design (3 learning conditions X 2 proficiency levels). As such, participants only took part in one group and were submitted to one experimental condition. The independent variables were teacher action demonstration applied for teaching students to play staccato and student proficiency level. The type of staccato used for the experiment involved two sequenced continuous movements: 1) wrist extension prior to hitting the piano key; and 2) wrist flexion while hitting the piano key, and afterwards (extension and flexion movements as used for the purposes of this study are described in Figure 1). Students' staccato learning was evaluated by the following two dependent variables: 1) Sound versus Inter-onset Duration Ratio (SIDR) (in relation to the staccato sound definition). SIDR was calculated by dividing note durations by their

respective inter-onset interval (in accordance with Bresin, 2001). The inter-onset interval measures the duration between one note onset and that of the next. The threshold value for slowest note decaying frequency was set at -30db, as suggested by Mason & Harrington, 2007). And 2) Range of Wrist Angle (RWA) (in accordance with the action demonstration employed during the experiment which was calculated as the difference between students' wrist flexion and extension in Degrees (see Figure 1); Reliability for RWA was established by Pearson's r correlation coefficient computed to assess reliability of observations undertaken by the researcher and those retrieved by an independent annotator on same video frames using 5% of the totality of frames of retention tests data (154 from a total of 3070 frames). There was a positive correlation between the values retrieved by the researcher and the annotator: $r = 0.98$, $n = 154$, $p = .0005$. The independent annotator was unaware of the specific teaching conditions participants were submitted to for the purposes of this experiment. Better staccato performance would be indicated by shorter note duration (low SIDR) and larger wrist rotation (higher RWA). Each trial consisted of each note of the scale performed by participants where SIDR and RWA could be obtained. The means of both measures (SIDR and RWA) were calculated to provide values for subsequent analysis. SIDR and RWA were evaluated by retention tests, as described in the following section.

[Figure 1 – here].

Procedure

Pre-test. In the pre-test participants were asked the following question by the researcher: “can you please play for me a few staccato notes in the piano?” In cases where participants were not acquainted with the term ‘staccato’ the researcher rephrased the question to: “can you please play for me a few short and detached notes in the piano?” video recordings were analysed to confirm if participants have or not employed the two sequenced and continuous movements in use for the action demonstration in study. Four participants

were excluded because they employed the two sequenced and continuous movements in use for the action demonstration in this study. Such exclusion is justified on the grounds that it would be impossible to associate these participants' results to the teaching conditions being tested in this study.

Training. The experiment took place during a short lesson carried out by the primary researcher, an experienced piano teacher with piano teaching experience of 22 years. All sessions of the experiment and associated tests (pre-tests and retention tests) were video recorded. Two different proficiency levels were tested: levels between pre-grade 1 and 3 (beginners), and those between 4 and 8 (intermediates). To keep similar conditions across groups, participants were asked to follow the instructions given by the researcher without talking or asking questions. The three (group exclusive) teaching conditions used in this study were: *audio-only*: audio representation of a staccato task; *blocked-observation*: observation of teacher's action demonstration followed by students' performance of the task – i.e. imitation of a set amount of teacher action demonstrations; and *interleaved-observation*: observation of teacher's action demonstration while alternating the performance of the task (student imitation of teacher's action demonstration) with the teacher's performance. The task represented during the teaching conditions and performed by participants during the experiment consisted of a staccato C major scale. The teaching conditions to which students were submitted and the task they were required to perform during the experiment are described in greater detail in Table 2.

[Table 2 – here]

Video teaching conditions were *not* considered appropriate for researching action demonstrations in this context because, firstly, formal learning of a musical instrument in the western world predominantly follows a one-to-one teaching/learning model – in which interaction between teacher and student is of a highly practical nature, and for which

imitation is an important component in the learning process. Secondly, it has elsewhere been shown that people tend to synchronize more accurately with a human partner than with a recording (Himberg, 2006). Thus the researcher prepared, memorised and rehearsed a monologue with equal verbal information and specified use of action and deictic gesture for all three groups in the experiment. Since communication in the classroom would seem unnatural if only the flexion and extension movements utilised in the action demonstration were used, the researcher elected to employ deictic (pointing) gestures on a limited and specified number of occasions (see Table 2). It was assumed that deictic gesture would help to instruct and direct participants in the required task without influencing their performances. Special care was taken in script preparation to ensure that the use of words, eye gaze, voice intonation, action and gestural performance were as uniform as possible across conditions. To ensure validity, all video recordings of the delivery of instruction during the experiment were viewed by the researcher and two independent annotators who evaluated researcher delivery performance in relation to the experiment components of the planned script: use of words, eye gaze, voice intonation and gestural performance. Multiple viewings of the same video material were undertaken as per annotators' choice enabled by the use of individual computer and headphones. The percentage of participants for which the script was followed exactly as planned for each dimension, according to the annotators' and researcher unanimous judgements was 72%. Errors on multiple dimensions occurred in 6% of the sample, that is three videos - one in each experimental condition and not for more than two dimensions at a time.

Retention tests. After the experiment/lesson, retention tests were carried out with all participants with same instructions given regardless of the type of experimental condition they were submitted to. Retention tests consisted of a student's performance of the same staccato scale performed during training for five consecutive times, *without* any type of

demonstration being given . These tests were carried out at three different points in time, as follows: Retention test 1 – immediately after the experiment; Retention 2 – twenty four hours after the experiment; and Retention 3 – eight days after the experiment.

Statistical analysis

Given that SIDR and RWA were measured using continuous scales (comprising of mean values of repeated measurements) at different points in time, ANOVA was considered the most suitable approach for analysis. Because the ages of the two proficiency groups were considerably different from each other, participant age was entered into the analysis of variance as a covariate (ANCOVA). Three sets of ANCOVA analyses were carried out for participants' SIDR and RWA measures, respectively for Pre-tests, Training and Retention Tests data. For Pre-tests and Training a two-way ANCOVA between subjects was carried out. Here the predictor variables were Student Proficiency Levels (beginners and intermediate) and Teaching Conditions (audio-only, blocked-observation and interleaved-observation). For the Retention Tests a three way mixed ANCOVA was undertaken for the predictor variables: Students Proficiency Levels (beginners and intermediate), Teaching Conditions (audio-only, blocked-observation and interleaved-observation), and the point in time at which the retention tests were carried out (Retention 1, 2 and 3). Additional post-hoc comparisons were made between pairs of categories. In addition, to allow for multiple testing between groups (and thus an increased risk of finding a significant result due to chance alone), the *p*-values from the post-hoc comparisons were given a Bonferroni adjustment.

Results

Pre-tests

Please note that pre-tests were aimed solely at evaluating participants' previous knowledge of the staccato task being taught during this experiment and since no Teaching

Condition was undertaken at the pre-test stage, the term Teaching Condition in this subsection refers only to the groups as divided for subsequent testing. Pre-tests were carried out after group allocation had taken place.

Sound and Movement. A two way ANCOVA between subjects for Students Proficiency Levels (beginners and intermediate) and Teaching Conditions (audio-only, blocked-observation and interleaved-observation) with participant age as covariate revealed no significant main effects or interactions (all $F_s < 1.33$, $p_s > .28$). This suggests that participants' results hereafter are not attributable to previous knowledge of the specific staccato task being taught in this experiment.

Training

Sound. There was a significant difference in SIDR of students submitted to different teaching conditions $F(2, 41) = 66.60$, $p < 0.001$, ($\mu_p^2 = .77$), measured in the trials of their first performance of the C major staccato scale. There was no significant difference in SIDR between student proficiency level groups, nor was there any significant effect of the covariate participant age ($F_s < .1$). Post-hoc tests revealed that in relation to SIDR, all groups significantly differed from each other during the experiment ($p < 0.001$): participants submitted to audio-only condition performed higher SIDR than participants in the other two conditions and participants in the interleaved-observation condition performed the lowest SIDR values in comparison to the other two groups and thus achieved better Staccatto.

Movement. There was a significant difference in RWA of students submitted to different teaching conditions $F(2, 41) = 38.16$, $p < .001$, $\mu_p^2 = .65$, measured in the trials of their first performance of the C major staccato scale. As with SIDR, there were no significant effects on RWA of proficiency or participant age ($F_s < .1$) Post-hoc tests revealed that RWA in the lesson was significantly different for all groups ($p < 0.001$): participants submitted to interleaved-observation presented higher RWA values, when compared to participants in

blocked-observation and participants in the audio-only condition, with this last group presenting the lowest RWA values.

Overall these results (for Sound and Movement) reveal that different teaching conditions yielded significantly different results for all groups in staccato performance during the lesson, regardless of students' specific proficiency levels. Better staccato performance was manifested in shorter note duration (low SIDR) and larger wrist rotation (higher RWA).

Retention

Sound. There was a significant difference in SIDR of students submitted to different teaching conditions $F(2, 41) = 7.91, p = .001, \eta_p^2 = .279$. Students who observed action demonstrations performed shorter notes than those who simply heard the target scales, with students in the interleaved-observation condition performing shorter notes than students submitted to the other two teaching conditions. Thus students who observed the action demonstration between each scale attempt were more proficient at staccato playing in each of the retention tests (in accordance with the staccato definition) than students in the other learning conditions. There was no significant difference in SIDR between student proficiency level groups, nor was there a significant effect of retention time or the covariate participant age, or of any interaction ($F_s < 1$).

[Figure 2 – Here]

Bonferroni-corrected post-hoc comparisons of the three conditions ($\alpha = .017$) showed significant differences between the Blocked-observation and the Sound conditions ($t(31) = 2.74, p = .01$), and between the Interleaved-observation and Sound conditions ($t(29) = 4.39, p < .001$), but not between the two observation and imitation conditions ($t(30) = 1.22, p = .23$). Put simply, students learned to play staccato more efficiently (shorter SIDR) when they have observed and imitated the teacher's action demonstration. This effect was not mediated by the proficiency level of the participants, nor by their age.

Movement. There was a significant difference in RWA of students submitted to different teaching conditions $F(2,41) = 27.96, p < .001, \mu_p^2 = .577$: students submitted to interleaved-observation rotated their wrist more (on average 26 degrees more) in comparison with students submitted to audio-only condition (which showed the lowest RWA values). In relation to blocked-observation, students submitted to interleaved-observation presented RWA values 17 degrees higher on average. As shown by these values, students submitted to interleaved-observation were more proficient at performing the desired action. The results showed no difference in RWA between student proficiency groups, RWA was not found to vary significantly over retention times, and the covariate participant age, had no significant effect on the results ($F_s < 1$) (see Figure 3).

[Figure 3 – Here]

Bonferroni-correct post-hoc comparisons of the teaching conditions revealed significant RWA differences in relation to students' specific teaching conditions (Sound / Blocked-observation: $t(31) = 3.71, p = .001$; Sound / Interleaved-observation: $t(29) = 9.17, p < .001$; Blocked- / Interleaved-observation: $t(31) = 4.50, p < .001$). . Contrary to what we had anticipated, intermediate proficiency level students did not achieve better learning retention results than beginners – or vice-versa – in any of the teaching conditions. However, all of those (beginners and intermediate) submitted to demonstrations involving repeated observations intercalated with students' immediate imitations of a teacher's demonstrations (interleaved-observation) achieved significantly better retention learning results than students submitted to other teaching conditions during training and associated retention tests. They have also produced movements with higher RWA in performing the action demonstration. The RWA values presented by these students remained stable across retention tests, implying that the effects of student observation and interleaved imitation of teacher action

demonstration on students' movements remained stable for at least eight days after the experiment was conducted.

Discussion

The findings of this study suggest an important role for the observation and imitation of teachers' action demonstration, both in terms of influence during learning in the moment (during the lesson) and in terms of knowledge retention for all student proficiency levels with relevant implications for pedagogical practice. Piano students presented considerably greater learning outcomes when submitted to teaching conditions in which they observed action demonstration and were requested to imitate during training and in retention tests in opposition to students that were only provided with an audio-only representation and verbal explanation of the task to be performed. This was evidenced by shorter relative note durations (in accordance with the staccato definition) and increased wrist rotation (in accordance with the action demonstration used for this specific study).

These findings are in contrast with Rosenthal's (1984) study where it was suggested that audio only conditions (of musical material) are efficient teaching strategies. In this comparison, it is important to bear in mind the methodological differences between these two investigations: Rosenthal's (1984) study population consisted of students in Higher Education and audio recorded only conditions consisted of *audio musical material* and *verbal instruction* to perform the musical material presented either in isolation or in a combined manner. Furthermore, the study in consideration did not include specific gestural, observation or imitational elements, and a musical piece was employed in opposition to the C major scale used here. While Rosenthal's investigation concludes that audio only conditions (of the musical material) are more effective for learning than verbal or a combination between verbal and audio, our study suggests that when compared with Blocked-observation and Interleaved-

observation, audio only conditions are considerably less effective for students between pre-grade and grade 8. Explanations for the discrepancy of findings could be: 1) differences between the characteristics of participants where students in Higher Education achieved a considerably higher level of expertise whereas students between pre-grade and grade 8 might need different type of scaffolding approaches (including observation and imitation) surpassing audio only. And 2) differences in the type of musical material used (i.e. musical piece and C major scale). A replication of this study with students at HE level and of Rosenthal's (1984) with pre-grade to grade 8 students would help clarifying these issues, particularly that so far whilst there is a considerable body of research focused upon skilled musicians, there remains a distinct lack of scholarly attention in the learning practices of musicians at the earliest stages of learning.

During learning in the moment (during the lesson – training) students submitted to Interleaved-observation condition performed significantly better staccato (both in terms of sound and movement). Although in agreement with Rohrer et al., (2015) maths study, these findings contradict results from several studies in motor learning research where better results were achieved at the training stage by participants in blocked conditions (e.g. Young, Cohen, & Husak, 1993; Del Rey, 1982; Del Rey, Wughalter & Carnes, 1987; Goode, 1986; Sekiya, Magill,& Anderson, 1996;Wulf, 1992). Both Blocked-observation and Interleaved-observation required effort during training, either to discriminate correct attempts in playing Staccato notes or to strengthen them. It might be that the type of Blocked-observation task employed here gave participants a certain level of assuredness of what sound and movement to use, without further opportunity for confirming if such assuredness was correct (as there was no further observation after participants' imitation). Whereas in the interleaved-observation condition each practice attempt provided opportunity for continuously seeking different solutions (due to alternation of observation and imitation) improving the ability to

learn critical features of the required task and enabling enhanced execution (for attempted explanations for the interleaving effect see Rohrer, 2012). Despite the commonalities between these two areas of skilled practice (i.e. sports and music), it becomes clear that a specific body of research specifically focused in instrumental music pedagogy that can inform teaching is needed.

Whilst observation and imitation were both present in both teaching conditions involving action demonstration, and both teaching conditions yielded positive learning outcomes, significantly greater learning effectiveness (both during training and in retention tests) resulted from observations that were intercalated with students' immediate imitation of researcher's demonstrations. This result provides evidence for the Associative Sequence Learning hypothesis based upon prediction and error (Cook et al., 2010; Cooper et al., 2013; Heyes & Ray, 2000) which suggests that experiencing a predictive relationship between observation and execution is important for motor learning. Indeed, repeated sets of intercalated observations and imitations in this study appeared to provide a higher predictive relationship between observation and execution, and therefore greater learning outcomes. Such learning outcomes spanned across time, with students submitted to interleaved-observation performing higher quality staccato in all retention tests in terms of sound and physical movement, in opposition to the other two groups with SIDR and RWA (range of wrist amplitude) values remaining stable during the three retention tests for each group. .

It is striking that there were no differences in terms of sound and physical movement across proficiency levels in the retention tests. Students in proficiency group II (grades 4-8) are in what can be considered as a 'middle' learning stage: they are not beginners and the next stage after grade 8 is a stage of a considerable skilled performance level. It would be expected that higher levels of musicianship would have generated alternative results as research in blocked and interleaving manipulations in motor learning suggests that skill level

and task difficulty influence the benefits of interleaving in motor learning (e.g. Farrow & Maschette, 1997; Pinto-Zipp & Gentile, 1995). However, despite being at an intermediate level of ability, their results in terms of staccato sound quality (SIDR) or range of wrist amplitude (RWA) during training and at the retention tests did not differ from students in the lower proficiency level group (pre-grade to grade 3). Reasons for this could be unfamiliarity with a staccato task that involved a new motor pattern to be learned and in which the entire study population was in a similar new learning situation (as evidenced by pre-tests results). Thus the absence of previous motor control tendencies, phase relationships (e.g. Kelso, J. & Zanone, 2002) or similar cognitive processes (e.g. Lee, 1988) can be suggested as possible reasons for such results. The current investigation has a number of limitations. Firstly, due to the small sample of participants, replication of this study is needed to bring forward more conclusive assuredness regarding the findings. Secondly, regarding the delivery of the script by the researcher, voice intonation requires a more in depth evaluation than the one undertaken here, to be sure of any subtle differences in how instructions were communicated. However, given the agreement between raters of instructor's presentations, it is unlikely that subtle intonation differences between conditions would lead to such substantial effects on musical performance. Thirdly, the study focus on demonstration for learning to perform a specific musical task (staccato playing) used a predefined demonstration implying that these findings shall be considered in relation to the specific task and demonstrations used. Thus, considerations regarding other musical tasks, as well as tasks in different skill domains, require further contextualised investigations.

In relation to further directions, judging by the findings, the way instrumental music teachers have been so far been using demonstration more frequently to beginner students than to more advanced students, needs to be reconsidered because as shown here, intermediate students equally benefitted from teacher action demonstrations. This also leads to conclude

that teachers teaching preparation courses should encompass higher focus on demonstration, as novice teachers have been shown elsewhere to demonstrate less than experienced teachers (see Goolsby, 1997). However, for this to occur, more investigations need to be undertaken in different instrumental music teaching contexts, focusing on a variety of other musical tasks and aimed at testing a variety of teacher demonstrations' possibilities.

While it may seem remote from this study focused on one-to-one piano teaching and learning, the same type of phenomena (deliberate intercalation, with feedback on physical and aural form) can be found for example in: ensemble marching performances, dance (traditional or originally choreographed), choirs, sports training, practices in medical contexts and in the contexts of arts and crafts, all of which share (in nature) similar educational aims regarding physical skill development and/or guided rehearsal. Greater considerations need therefore to be given to the role of educators' intercalated or interactive demonstrations in pedagogical contexts involving acquisition of specific motor skills in order to devise ways in which observation and imitation can be strategically used for optimising learning effectiveness.

Conclusion

The findings of this study suggest not only an important role for the observation and imitation of teacher's action demonstrations for students' learning in terms of knowledge retention, but also that certain teaching and learning conditions (involving different combinations of observation and imitation elements) are more effective than others. Greater learning effectiveness resulted from observations that were intercalated with students' immediate imitation of teacher's action demonstrations, in comparison to a block of observations followed by a block of imitations to both, beginner and intermediate proficiency level piano students. In contexts where the intended learning outcomes involve the embodiment of

abstract concepts in a motor activity, ascribing certain degrees of effectiveness to action demonstration strategies implies two things: firstly, a need to consider such action demonstrations as communicational and an integral aspect of the content to be learned; and secondly, that empirical work should be carried out to unravel specific action and gestural performance demonstrations that can enhance motor learning across group-specific pedagogical contexts. The findings point to a need for a pedagogical reconceptualization in piano, instrumental music and in contexts of practical physical skill development and/or guided rehearsal to include considerations on the use of demonstration strategies. Thus, the training of music educators (and educators in other areas), presently highly focused on content and curriculum, needs to be expanded to include considerations into the development of interactive teaching and learning styles that can promote efficient learning. It is only upon recognition of the role and importance of teachers' demonstrations and the interconnectedness of perceptual and motoric aspects that a much needed embodied and empirical gestural pedagogy can be developed for teaching conceptual and embodied practical elements directed not only to students, but also to prospective teachers.

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Ethical Approval

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Table 1

Participants' characteristics: gender, age range, average of time of engagement in formal piano tuition per experiment condition.

Teaching condition	Group I				Group II			
	Gender		Age range	Average experience*	Gender		Age range	Average Experience*
	Female	Male			Female	Male		
Audio-only	4	4	5 to 14	1 year	3	4	13 to 44	11 years
Blocked- observation	5	3	8 to 14	1 year	7	2	12 to 23	7 years
Interleaved- observation	8	1	6 to 9	1 year	5	2	11 to 22	6 years
Total	17	8		1 year	15	8		8 years

Note. * Average time participants were engaged in formal piano teaching and learning

Table 2

Description of teaching and learning conditions used in the experiment

Condition	Instruction given to participants		Demonstration given to participants		Participant's task
	Verbal	Gestural	Activity	Gestural	
Audio-only	Explanation of how to perform an ascending staccato scale starting on middle C, focusing on staccato definition in terms of sound quality	Two Deictic gestures	Audio recording of a staccato scale, starting on middle C listened five consecutive times	None	To play a staccato scale, starting on middle C, five times, using only second finger of the right hand, after listening to the audio recording.
Blocked-observation	Explanation of how to perform an ascending staccato scale starting on middle C, focusing on staccato definition in terms of sound quality	Two Deictic gestures	Researcher performs a staccato scale, starting on middle C, five <i>consecutive</i> times	Action demonstration * for each note	To <i>observe</i> the demonstration and <i>play</i> the same staccato scale <i>afterwards</i> , five times.
Interleaved-observation	Explanations of how to perform an ascending staccato scale starting on middle C, focusing on staccato definition in terms of sound quality	Two Deictic gestures	Researcher performs a staccato scale, starting on middle C, <i>alternating</i> each of the five staccato scales, with student's performance.	Action demonstration * for each note	To <i>observe</i> and <i>play</i> the staccato scale while <i>intercalating</i> each scale with researcher's demonstrations.

Note. * A total of eight action demonstrations were performed for each staccato scale (one for each note of the scale). A description of the action demonstration as performed for the experiment can be seen in figure 1.

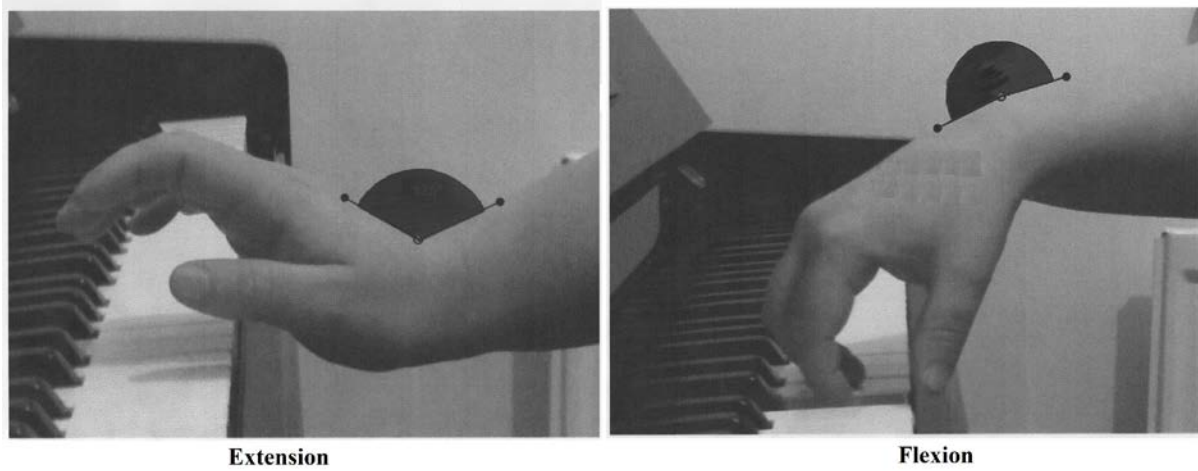


Figure 1. Description of the extension and flexion movements used to perform the action demonstration performed for this study.

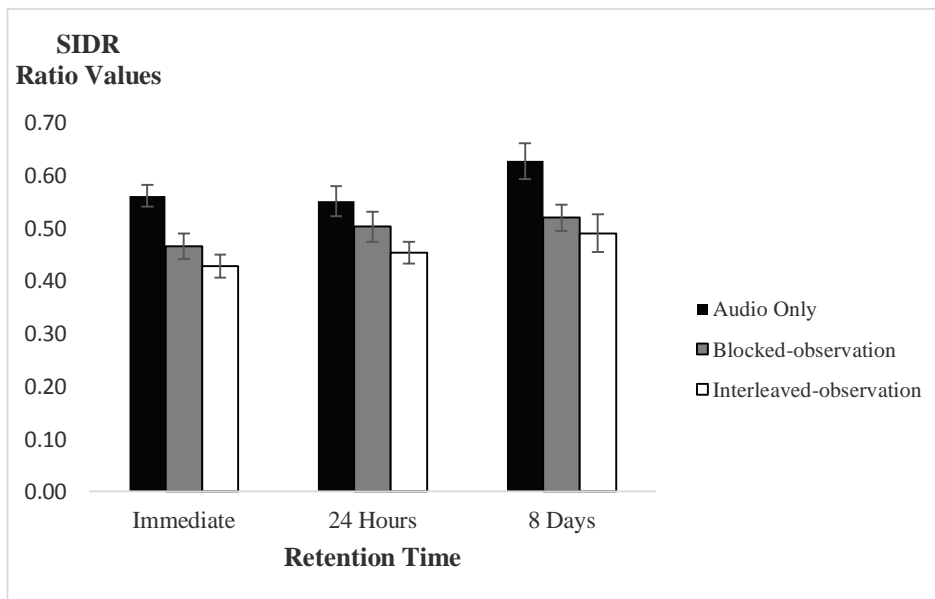


Figure 2. SIDR (Sound vs. Inter-Onset Duration Ratio) mean values overtime, per teaching condition, for all students (proficiency groups I and II combined). Lower values indicate more staccato playing, which was the goal of the task. Error bars represent standard errors.

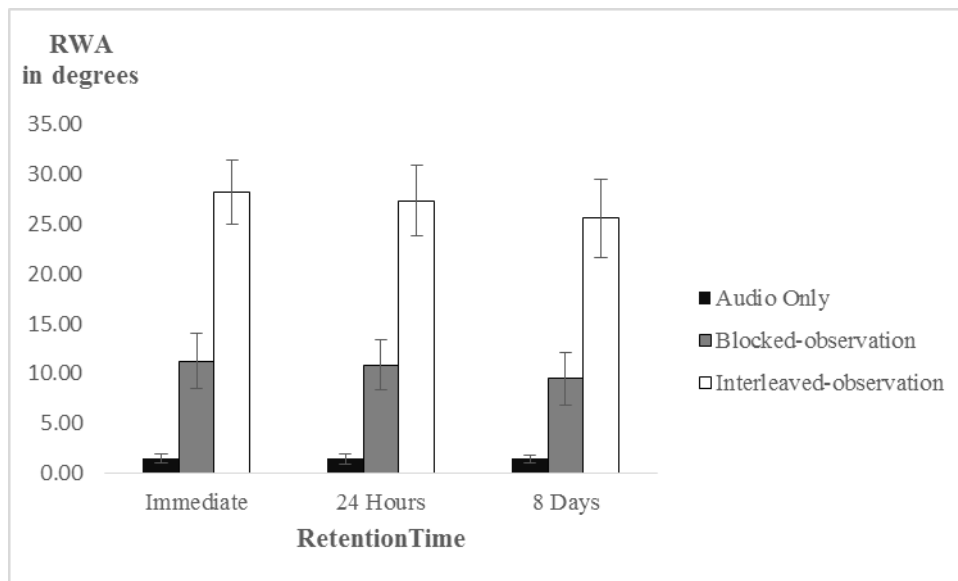


Figure 3. RWA (Rotation of Wrist Amplitude) mean values overtime, per teaching condition, for all students (proficiency levels I and II combined). Higher values indicate more staccato playing, which was the goal of the task. Error bars represent standard errors.

